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[ETD 8: High Voltage Switchgear and Controlgear]

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Indian Standard

GAS INSULATED METAL ENCLOSED SWITCHGEAR FOR RATED VOLTAGES OF 72.5 kV AND ABOVE — SPECIFICATION

ICS 29.120.60

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

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High Voltage Switchgear and Controlgear Sectional Committee, ET 08

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Indian Standard

GAS INSULATED METAL ENCLOSED SWITCHGEAR FOR RATED VOLTAGES OF 72.5 kV AND ABOVE — SPECIFICATION

NATIONAL FOREWORD

This Indian Standard which is identical to IEC Pub 517 (1990) Gas insulated metal enclosed switchgear for rated voltages of 72 5 kV and above issued by the International Electrotechnical Commission was adopted by the Bureau of Indian Standards on the recommendations of the High Voltage Switchgear and Controlgear Sectional Committee ET 08 and approval of the Electrotechnical Division Council

The text of the IEC Standard along with its Amendment No 1 has been approved as suitable for publication as Indian Standard without deviations

This standard specifies requirements for gas insulated metal enclosed switchgear in which the insulation is obtained at least partly by an insulating gas other than air for alternating current of rated voltages of 72 5 kV and above

In this standard certain terminology and conventions are not identical with those used in Indian Standard Attention is specially drawn to the following

a) Wherever the words International Standard appear referring to this standard they should be read as Indian Standard

b) Comma ( ) has been used as a decimal marker while in Indian Standards the current practice is to use a point ( ) as the decimal marker

Only the English language text in the International Standard has been retained while adopting it in this Indian Standard

For the purpose of deciding whether a particular requirement of this standard is complied with the final value observed or calculated expressing the result of a test or analysis shall be rounded off in accordance with IS 2 1960 Rules for rounding off numerical values (*revised*) The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard

In this standard reference appears to certain International Standards for which Indian Standards also exist The corresponding Indian Standards which are to be substituted in their place are listed below along with their degree of equivalence

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 44 4 1980 Instrument transformers Part 4 Measurement of partial discharge	IS 11322 1985	Partially equivalent
IEC 50 (151) 1978 International Electrotechnical Vocabulary Chapter 151 Electrical and magnetic devices	IS 1885 (Part 74) 1979	Identical
IEC 50 (441) 1984 International Electrotechnical Vocabulary Chapter 441 Switchgear controlgear and fuses	IS 1885 (Part 17) 1979	Technically equivalent

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 56 1987 High voltage AC circuit breakers	IS 13118 1991	Identical
IEC 60-2 1973 High voltage test techniques, Part 2 Test procedures	IS 2971 (Part 2) 1974	Technically equivalent
IEC 129 1984 AC disconnectors and earthing switches	IS 9921 (Parts 1 to 4)	Technically equivalent
IEC 137 1984 Bushings for AC voltages above 1000 V	IS 2099 1986	Technically equivalent
IEC 141 Tests on oil failed and gas pressure cables and their accessories		No ISS Exists
IEC 270 1981 Partial discharge measurements	IS 6209 1982	Technically equivalent
IEC 298 1990 AC metal enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV	Under print	Identical
IEC 480 1974 Guide for the checking of SF6 taken from electrical equipment		No ISS Exists
IEC 529 1989 Degree of protection provided by enclosures (IP Code)	IS 12063 1987	Technically equivalent
IEC 651 1979 Sound level meters	IS 9779 1981	Technically equivalent
IEC 694 1980 Common clauses for high voltage switchgear and controlgear standards	IS 12729 1988	Technically equivalent
IEC 859 1986 Cable connections for gas insulated metal enclosed switchgear for rated voltages of 72 5 kV and above		No ISS Exists

1 Scope

This standard specifies requirements for gas-insulated metal-enclosed switchgear in which the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure, for alternating current of rated voltages of 72,5 kV and above, for indoor and outdoor installation and for service frequencies up to and including 60 Hz

For the purpose of this standard the term "switchgear" is used for "gas-insulated metal-enclosed switchgear"

The gas-insulated metal-enclosed switchgear covered by this standard consists of individual components intended to be directly connected together and able to operate only in this manner

This standard completes and amends, if necessary, the various relevant standards applying to the individual components constituting gas-insulated metal enclosed switchgear

Unless otherwise specified, the gas-insulated metal enclosed switchgear is designed to be used under normal service conditions

2 Normal and special service conditions

Refer to clause 2 of IEC 694, with the following modification

At any altitude the dielectric characteristics of the internal insulation are identical with those measured at sea-level For this insulation, therefore, no requirements concerning the altitude are applicable

3 Definitions

For the definitions of general terms used in this standard, reference is made to IEC 50(441) and 50(151) The following definitions apply for the purpose of this standard

3 101 *Switchgear*

A general term covering switching devices and their combination with associated control measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy (IEV 441-11-02)

3 102 *Metal-enclosed switchgear and controlgear*

Switchgear and controlgear assemblies with an external metal enclosure intended to be earthed, and complete except for external connections (IEV 441-12-04)

3 103 *Gas-insulated metal-enclosed switchgear*

Metal-enclosed switchgear in which the insulation is obtained, at least partly, by an insulating gas other than air at atmospheric pressure (IEV 441-12-05)

NOTE This term generally applies to high voltage switchgear and controlgear

3 104 *Transport unit*

A part of gas-insulated switchgear suitable for shipment without being dismantled

3 105 *Enclosure*

A part of gas-insulated metal-enclosed switchgear retaining the insulating gas under the prescribed conditions necessary to maintain safely the rated insulation level, protecting the equipment against external influences and providing a high degree of protection to personnel

3 106 *Compartment*

A part of gas-insulated metal-enclosed switchgear, totally enclosed except for openings necessary for interconnection and control

NOTE A compartment may be designated by the main component contained therein e g circuit breaker compartment busbar compartment

3 107 *Component*

An essential part of the main or earthing circuits of gas-insulated metal-enclosed switchgear which serves a specific function (for example circuit-breaker, disconnector, switch, fuse, instrument transformer, bushing, busbar, etc)

3 108 *Partition*

A part of gas-insulated metal-enclosed switchgear separating one compartment from other compartments (IEV 441-13-06)

3 109 *Bushing*

A structure carrying one or more conductors through an enclosure and insulating it therefrom, including the means of attachment

3 110 *Main circuit*

All the conductive parts of gas-insulated metal-enclosed switchgear included in a circuit which is intended to transmit electrical energy (IEV 441-13-02)

3 111 *Auxiliary circuit*

All the conductive parts of gas-insulated metal-enclosed switchgear included in a circuit (other than the main circuit) intended to control, measure, signal and regulate (IEV 441-13-03)

NOTE The auxiliary circuits of gas insulated metal enclosed switchgear include the control and auxiliary circuits of the switching devices

3 112 *Rated value*

A quantity value assigned, generally by a manufacturer, for a specified operating condition of gas insulated metal-enclosed switchgear (IEV 151-04-03)

NOTE See clause 4 for individual rated values

3 113 *Ambient air temperature (of gas insulated metal-enclosed switchgear)*

The temperature, determined under prescribed conditions, of the air surrounding the external enclosure of gas-insulated metal-enclosed switchgear

3 114 *Design temperature (of the enclosure)*

The highest temperature which can be reached by the enclosure under service conditions

3 115 *Design pressure (of the enclosure)*

The pressure used to determine the thickness of the enclosure

3 116 *Disruptive discharge*

Phenomena associated with the failure of insulation under electric stress, in which the discharge completely bridges the insulation under test, reducing the voltage between the electrodes to zero or almost zero

NOTES

1 The term applies to discharges in solid liquid and gaseous dielectrics and to combinations of these

2 A disruptive discharge in a solid dielectric produces permanent loss of dielectric strength (non self restoring insulation) in a liquid or gaseous dielectric the loss may be only temporary (self restoring insulation)

3 The term "sparkover" is used when a disruptive discharge occurs in a gaseous or liquid dielectric The term "flashover" is used when a disruptive discharge occurs over the surface of a solid dielectric in a gaseous or liquid medium The term "puncture" is used when a disruptive discharge occurs through a solid dielectric

4 Rating

The rating of gas-insulated metal-enclosed switchgear comprises the following:

a) rated voltage and number of phases;

b) rated insulation level;

c) rated frequency;

d) rated normal current (for main circuits);

e) rated short-time withstand current (for main and earthing circuits);

f) rated peak withstand current (for main and earthing circuits),

g) rated duration of short-circuit;

h) rated values of the components forming part of gas-insulated metal-enclosed switchgear, including their operating devices and auxiliary equipment;

i) rated density of gas for insulation.

The co-ordination of rated voltages, rated short-time withstand currents, rated peak withstand currents and rated normal currents of gas-insulated metal-enclosed switchgear is under consideration.

4 1 *Rated voltage*

Refer to 4.1 and 4.1.2 of IEC 694 with the addition of the rated value 72,5 kV

NOTE - Components forming part of the switchgear may have individual values of rated voltage in accordance with the relevant standards

4.2 *Rated insulation level*

Refer to 4.2 of IEC 694 with the addition of the following supplement:

The switchgear comprises components having a definite insulation level. Although internal faults can largely be avoided by the choice of a suitable insulation level, measures to limit external overvoltages (surge arresters, protective sparkgaps) should be considered.

NOTES

1 Regarding the external parts of bushings (if any), refer to IEC 137

2 The waveforms are accepted lightning impulse and switching impulse shapes, pending the results of studies on the ability of this equipment to withstand other types of impulses

3 The choice between alternative insulation levels for a particular rated voltage should be based on insulation co-ordination studies taking into account also the self-generated transient overvoltages due to switching

4.3 *Rated frequency*

Refer to 4.3 of IEC 694 with the addition of the following rated values:

16 $^2/_3$ Hz and 25 Hz

4.4 *Rated normal current and temperature rise*

4.4.1 *Rated normal current*

Refer to 4.4.1 of IEC 694 with the addition of the following paragraph:

Some main circuits of gas-insulated metal-enclosed switchgear (e.g. busbars, feeder circuits, etc.) may have different values of rated normal current. They should preferably be selected from the following values:

1 250 A – 2 000 A – 3 150 A – 4 000 A · 6 300 A

4.4.2 *Temperature rise*

Refer to 4.4.2 of IEC 694 with the addition of the following supplement:

The temperature rise of components contained in the switchgear which are subject to standards not covered by the scope of IEC 694 shall not exceed the temperature-rise limits permitted in the relevant standard for those components.

The temperature rise for accessible enclosures shall not exceed 30 K. In the case of enclosures which are accessible but need not be touched during normal operation, the temperature-rise limit may be increased to 40 K.

NOTE - When applying a temperature rise equal to or higher than 65 K for parts of the enclosure not accessible to the operator, every precaution is to be taken to ensure that no damage is caused to the surrounding insulating materials

4.5 *Rated short-time withstand current*

Refer to 4.5 of IEC 694 with the addition of the following paragraph:

The rated short-time withstand current should preferably be selected from the following values:

25 kA – 31,5 kA – 40 kA – 50 kA – 63 kA – 80 kA – 100 kA

4.6 *Rated peak withstand current*

Refer to 4.6 of IEC 694.

NOTE In principle, the rated short-time withstand current and the rated peak withstand current of a main circuit cannot exceed the corresponding rated values of the weakest of its series connected components

4.7 *Rated duration of short-circuit*

Refer to 4.7 of IEC 694.

4.8 *Rated supply voltage of closing and opening devices and auxiliary circuits*

Refer to 4.8 of IEC 694.

4.9 *Rated supply frequency of operating devices and auxiliary circuits*

Refer to 4.9 of IEC 694 with the addition of the following paragraph:

The rated supply frequency of operating devices and auxiliary circuits is the frequency at which the conditions of operation and temperature rise of these devices and circuits are determined.

4.10 *Rated pressure of compressed gas supply for operating mechanisms*

Refer to 4.10 of IEC 694 with the addition of the following paragraph:

The pressure of the compressed gas supply is understood to be the pressure measured in the reservoir immediately before the operation.

4.101 *Rated density of gas for insulation*

The rated density of gas for insulation is the density assigned by the manufacturer at which the switchgear is intended to be used in service.

The minimum gas density is the value of the density assigned by the manufacturer at and above which the rated insulation level applies.

Gas-insulated metal-enclosed switchgear may have several rated and minimum gas densities for insulation, differing from one compartment to another.

5 Design and construction

Gas-insulated metal-enclosed switchgear shall be designed so that normal service, inspection and maintenance operations, earthing of connected cables, locating of cable faults, voltage tests on connected cables or other apparatus and the elimination of dangerous electrostatic charges, can be carried out safely, including the checking of phase sequence after erection and extension.

The design of the equipment shall be such that the agreed permitted movement of foundations or thermal effects do not impair the assigned performance of the equipment.

All components of the same rating and construction which may need to be replaced shall be interchangeable.

The various components contained within the enclosure are subject to their relevant standards except where modified by this standard.

5.1 *Requirements for liquids in switchgear and controlgear*

Refer to 5.1 of IEC 694.

5.2 *Requirements for gases in switchgear and controlgear*

Refer to 5.2 of IEC 694.

NOTE - For checking of sulphur hexafluoride in service, refer to IEC 480

5.3 *Earthing*

Refer to 5.3 of IEC 694.

5.3.101 *Earthing of the main circuits*

To ensure safety during maintenance work all parts of the main circuits to which access is required or provided shall be capable of being earthed. In addition, it shall be possible, after the opening of the enclosure, to connect earth electrodes for the duration of the work.

Earthing may be made by:

a) earthing switches with a making capacity equal to the rated peak withstand current, if there is no certainty that the circuit connected is not live;

b) earthing switches without a making capacity or with a making capacity lower than the rated peak withstand current, if there is certainty that the circuit connected is not live;

c) removable earthing devices, only by agreement between manufacturer and user.

5.3.102 *Earthing of the enclosure*

The enclosures shall be capable of being connected to earth. All metal parts intended to be earthed, which do not belong to a main or an auxiliary circuit, shall be connected to earth. For the interconnection of enclosures, frames, etc., fastening (e.g. bolting or welding) is acceptable for providing electrical continuity.

The continuity of the earthing circuits shall be ensured taking into account the thermal and electrical stresses caused by the current they may have to carry.

5.4 *Auxiliary equipment*

Refer to 5.4 of IEC 694.

5.5 *Dependent power closing*

Refer to 5.5 of IEC 694.

5.6 *Stored energy closing*

Refer to 5.6 of IEC 694.

5.7 *Operation of releases*

Refer to 5.7 of IEC 694.

5.8 *Low and high pressure interlocking devices*

Refer to 5.8 of IEC 694 with the addition of the following supplement:

For gas-insulated metal-enclosed switchgear it is recommended that a signal be provided when the gas density or gas pressure for insulation has fallen to the minimum value (see 4.101).

5.9 *Nameplates*

Refer to 5.9 of IEC 694 with the addition of the following supplement:

Gas-insulated metal-enclosed switchgear, all its operating devices and main components, as agreed between manufacturer and user, shall be provided with durable and clearly legible nameplates which shall contain the following information:

- manufacturer's name or trade mark;
- type designation or serial number.

It is recommended that the following data are also given·

- rated voltage;
- rated normal currents for busbars and circuits;
- rated frequency;
- rated short-time withstand current;
- rated pressure for operation;
- minimum gas density for insulation;
- design pressure for enclosures.

The individual nameplates of the components can be simplified provided common information for the switchgear is stated on one nameplate.

NOTE - The word "rated" need not appear on the nameplates

5.101 *Degree of protection*

5.101.1 *Degree of protection for the main circuits*

No specification applies to the main circuit and parts directly connected thereto.

5.101.2 *Degree of protection for auxiliary circuits and moving parts*

The degree of protection of persons against contact with live parts of auxiliary circuits and with any moving part (other than smooth rotating shafts and moving linkages) shall be indicated by means of one of the designations specified in table I.

The characteristic numeral indicates the degree of protection provided by the enclosure with respect to persons, also to the equipment inside the enclosure.

Table I gives details of objects which will be "excluded" from the enclosure for each of the degrees of protection.

The term "excluded" implies that a part of the body or an object held by a person, either will not enter the enclosure or, if it enters, that adequate clearance will be maintained and no moving part will be touched.

Equipment for outdoor installation provided with appropriate protection features shall be indicated by the characteristic letter W placed immediately after the letters IP.

The relevant service conditions shall be observed (see clause 2) in order to protect the equipment against atmospheric agents.

Table 1 – Degrees of protection against ingress of foreign solid objects and against access to live or moving parts

Designation	Definition
IP2X	Protected against solid objects greater than 12 mm in diameter and fingers or similar objects not exceeding 80 mm in length
IP3X	Protected against tools, wires, etc., of diameter or thickness greater than 2,5 mm and solid objects exceeding 2,5 mm in diameter
IP4X	Protected against wires or strips of diameter or thickness greater than 1,0 mm and solid objects exceeding 1,0 mm in diameter
IP5X	Dust-protected, the ingress of dust is not totally prevented but dust does not interfere with satisfactory operation of the equipment

NOTE - The designation of the degree of protection corresponds to IEC 529 No degree of protection for auxiliary circuits against harmful ingress of water is specified In case of IP5X, category 2 is applicable

5.102 *Internal fault*

5.102.1 *General*

A fault leading to arcing within gas-insulated metal-enclosed switchgear built to this standard has a low order of probability. This results from the application of an insulating fluid other than air at atmospheric pressure which will not be altered by pollution, humidity or vermin. Further, the insulating qualities may be checked by dielectric tests on assembled units in the factory and on site. While the probability of such a fault is low, the probability of a fault occurring with personnel present is even lower, especially since gas-insulated sub-stations are closed electrical operating areas, the access to which is permitted only to authorized personnel.

Examples of measures to avoid arcing due to an internal fault and to limit duration and consequences are:

- insulation co-ordination;
- gas-leakage limitation and control;
- high-speed protection;
- high-speed arc short-circuiting devices;
- interlocking of switching devices;
- remote control;
- internal and/or external pressure reliefs;
- checking of workmanship on site.

Arrangements should also be made to minimize the effects of internal faults leading to arcing on the continued service capability of the switchgear. The effect of an arc should be confined to the compartment in which the arc has been initiated, or to the other compartments in the faulty section, if pressure relief is used between compartments within this section. After disconnection of the compartment or section, restoration of the normal operation of the remaining equipment should be possible.

If, in spite of the measures taken, a test is agreed between manufacturer and user to verify the effect of arcing due to an internal fault, this test should be in accordance with 6.106.

Tests would normally not be necessary in the case of single-phase enclosed switchgear installed in isolated neutral or resonant earthed systems and equipped with a protection to limit the duration of internal earth faults.

5.102.2 *External effects of the arc*

In order to provide a high protection to personnel the external effects of an arc shall be limited (by a suitable protective system) to the appearance of a hole or tear in the enclosure without any fragmentation.

The manufacturer shall provide sufficient information regarding the protective system employed.

Manufacturer and user may agree upon a time during which an arc due to an internal fault up to a given value of short-circuit current will cause no external effects.

5.102.3 *Internal fault location*

The manufacturer of the switchgear should propose appropriate measures for fault location, if required by the user.

5.103 *Enclosures*

5.103.1 *General*

The enclosure shall be of metal, permanently earthed and capable of withstanding the normal and transient pressures to which it is subjected in service.

While the enclosures of gas-filled equipment conforming to this standard are permanently pressurized in service they are subjected to particular conditions of service which distinguish them from compressed air receivers and similar storage vessels. These conditions are:

- enclosures envelop the main circuit not only to prevent hazardous approach to live or moving parts but are so shaped that when filled at or above the minimum gas density for insulation (see 4.101) they ensure that the rated insulation level (see 4.2) for the equipment is achieved (electrical rather than mechanical considerations predominate in determining the shape and materials employed);

- enclosures are normally filled with a non-corrosive gas, thoroughly dried, stable and inert; since measures to maintain the gas in this condition with only small fluctuations in pressure are fundamental to the operation of the switchgear and since the enclosures will not be subject to internal corrosion, there is no need to make allowances for these factors in determining the design of the enclosures (however, the effect of possible transmitted vibrations should be taken into account);
- the service pressure employed is relatively low.

For outdoor installation, the manufacturer shall take into account the influence of climatic conditions (see clause 2).

5.103.2 *Design of enclosures*

The wall thickness of the enclosure shall be based on the design pressure as well as the following minimum withstand durations without burn-through:

- 0,1 s for currents of 40 kA and above;
- 0,2 s for lower currents.

Pending international agreement on a standard procedure, methods for the calculation of the thickness and the construction of enclosures either by welding or casting may be chosen from established pressure vessel codes based on the design temperature and design pressure defined in this standard.

NOTE - When designing an enclosure, account should also be taken of the following

a) the possible evacuation of the enclosure as part of the normal filling process,

b) the full differential pressure possible across the enclosure walls or partitions,

c) the resulting pressure in the event of an accidental leak between the compartments in the case of adjacent compartments having different service pressures,

d) the possibility of the occurrence of an internal fault (see 5 102)

The design temperature of the enclosure is generally the upper limit of ambient air temperature increased by the temperature rise due to the flow of rated normal current. Solar radiations should be taken into account when they have a significant effect.

The design pressure of the enclosure is at least the upper limit of the pressure reached within the enclosure at the design temperature.

In determining the design pressure of the enclosure, the gas temperature shall be taken as the mean of the upper limits of the enclosure temperature and the main circuit conductor temperature with rated normal current flowing unless the design pressure can be established from existing temperature-rise test records.

For enclosures and parts thereof, the strength of which has not been fully determined by calculation, proof tests (see 6.104) shall be performed to demonstrate that they fulfil the requirements.

Materials used in the construction of enclosures shall be of known and certified minimum physical properties on which calculations and/or proof tests are based. The manufacturer shall be responsible for the selection of the materials and the maintenance of these minimum properties, based on certification of the material supplier, or tests conducted by the manufacturer, or both.

5.103.3 *Gas tightness*

Because compressed gas is used for insulation a high degree of tightness is required for the enclosure. The permissible annual or daily escape of gas and the time between refillings for each type of compartment and for the complete installation should be stated by the manufacturer in accordance with annex DD.

If requested by the user, in order to permit maintenance in a compartment when adjacent compartments contain gas under pressure, the permissible gas leakage across partitions should also be stated by the manufacturer.

5.104 *Partitions*

Gas-insulated metal-enclosed switchgear shall be divided into compartments in such a manner that both the normal operating conditions are met and a limitation of the effects of an arc inside the compartment is obtained (see 5.102.1).

For this purpose partitions are required to ensure that the dielectric characteristics in one compartment are not substantially altered when an adjacent compartment is at reduced pressure due to leaks or maintenance operations. They are generally of insulating material but are not intended by themselves to provide electrical safety of personnel, for which other means such as earthing of the equipment may be necessary; they shall, however, provide mechanical safety against the normal gas pressure still present in the adjacent compartment.

A partition separating a compartment filled with insulating gas from a neighbouring compartment filled with liquid, such as a cable box or a voltage transformer, shall not show any leakage affecting the dielectric properties of the two media.

5.105 *Pressure relief*

Pressure relief devices in accordance with this subclause shall be arranged so as to minimize the danger to an operator during the time he is performing his normal operating duties in the gas-insulated substation if gases or vapours are escaping under pressure.

NOTE - The term "pressure relief device" includes both pressure relief valves, characterized by an opening pressure and a closing pressure, non-reclosing pressure relief devices, such as diaphragms and bursting disks

5.105.1 *Pressure relief valves to limit maximum filling pressure*

In the case of an enclosure permanently connected to a compressed gas supply, the devices employed for pressure regulation cannot be relied upon to prevent overpressure. Pressure relief valves of adequate size shall be fitted to prevent the pressure within the enclosure from rising to more than 10 % above the design pressure in the event of failure of the pressure regulation means.

In the case of enclosures not permanently connected to a compressed gas supply, a pressure relief valve shall be fitted to the filling pipe to prevent the gas pressure from rising to more than 10 % above the design pressure during the filling of the enclosure Alternatively the valve may be fitted to the enclosure itself.

After an opening operation of a pressure relief valve, it shall reclose before the pressure has fallen to 75 % of the design pressure.

The filling pressure should be chosen to take into account the gas temperature at the time of filling, for example checking by temperature-compensated pressure gauges

5.105.2 *Pressure relief devices to limit pressure rise in the case of an internal fault*

Since after an arc due to an internal fault the damaged enclosures will be replaced, pressure relief devices need only be proportioned to limit the external effects of the arc (see 5.102.2).

In some designs pressure relief may be achieved by allowing the arc to burn through the enclosure at designated points. Where such means are employed the resultant hole is deemed to be a pressure relief device and consequently should fulfil the requirements given in 5.105

NOTES

1 In the case of an internal fault which causes yielding of the enclosure, the adjacent enclosures should be checked for absence of distorsion

2 When bursting disks are used for pressure relief due regard should be paid to their rupture pressure in relation to the design pressure of the enclosure (see 3 115) to reduce the possibility of unintentional rupture of the disk

5 106 *Disconnectors and earthing switches*

The devices for ensuring the isolating distance between high-voltage conductors are considered to be disconnectors which shall comply with IEC 129 Additional requirements are given in 6 102 and 7 104

The requirement of IEC 129, that it shall be possible to know the operating position of the disconnector or earthing switch, is met if the position of the disconnector or earthing switch is indicated by a reliable indicating device

The co-ordination of the insulation levels to earth and of the isolating distance is not necessarily obtained by the construction or design of the switchgear. Surge arresters or other means are recommended to perform such a co-ordination. For this type of switchgear, there is no additional requirement necessary apart from the insulation level for the isolating distance, which shall be in accordance with item b) of 6 1 4

It shall not be possible for the disconnector or earthing switch to open or to close inadvertently due to forces which may occur in service, including those due to a short-circuit

5 107 *Interlocks*

Interlocks between different components of the equipment are provided for reasons of safety and for convenience of operation The following provisions are mandatory for main circuits

- apparatus installed in main circuits, which are used for ensuring isolating distances during maintenance work, shall be secured against reclosure,
- earthing switches shall be secured against reopening

It is recommended that earthing switches having a short-circuit making capacity less than the rated peak withstand current of the circuit should be interlocked with the associated disconnectors

It is recommended that switches having a short-circuit making capacity less than the rated peak withstand current, or a breaking capacity less than the rated normal current, and disconnectors should be interlocked with the associated circuit-breaker to prevent opening or closing of the switch or disconnector unless the associated circuit-breaker is open. If the disconnectors are fitted with metallic screens, the interlock between contacts and metallic screens shall prevent

- the metallic screen being interposed, if the contacts are not completely open,
- the contacts from being closed, if the metallic screen is not completely retracted

The provision of additional or alternative interlocks shall be subject to agreement between manufacturer and user. The manufacturer shall give all necessary information on the purpose and function of interlocks

5.108 *Noise*

During an operation, the level of noise emitted by the switchgear should not exceed a specified value. This value and the procedure of verification should be agreed between manufacturer and user (see IEC 651).

5.109 *Provisions for dielectric tests on cables*

Those parts of the gas-insulated metal-enclosed switchgear which remain connected to the cable shall be capable of withstanding the cable test voltages specified in the relevant cable standards for the same rated voltage (for oil-filled and gas-pressure cables see IEC 141)

If it is not acceptable to apply d c cable test voltages to the switchgear, special provisions for cable testing are to be made (e.g disconnecting facilities and/or increasing of the gas density for insulation)

During dielectric tests on cables in general, the adjacent parts of the switchgear should be de-energized and earthed, unless special measures are taken to prevent disruptive discharges in the cable affecting the energized parts of the switchgear

The location of suitable bushings for cable testing with d c and/or a c voltages should be provided at the cable connection enclosure or at the switchgear itself (see IEC 859)

NOTE Attention is drawn to the fact that practically no safety margin is left in some cases between the rated power frequency test voltage for the isolating distance and the resulting voltage stress across the isolating distance due to the application of the d c cable test voltage while the other side of the isolating distance of the switchgear is still alive

6 Type tests

Refer to clause 6 of IEC 694 with the addition of the following

Components contained in gas-insulated metal-enclosed switchgear which are subject to standards not covered by the scope of IEC 694 shall comply with and be tested in accordance with those standards, taking into account the conditions given in the following subclauses

As a general rule, tests on switchgear components are carried out in accordance with the relevant standards of the apparatus

In general type testing shall be carried out on a complete single-pole or three-pole functional unit of a typical switchgear bay Where this is impracticable, the type tests can be made on representative assemblies or sub-assemblies

Because of the variety of types, ratings and possible combinations of components, it is impracticable to subject all arrangements of the switchgear to type tests The performance of any particular arrangement may be substantiated by test data of comparable arrangements

The type tests and verifications comprise.

	Subclause
1) *Normal type tests*	
a) Tests to verify the insulation level of the equipment including partial discharge tests and dielectric tests on auxiliary circuits	6 1
b) Tests to prove the temperature rise of any part of the equipment and measurement of the resistance of the main circuit	6 3 and 6 4
c) Tests to prove the ability of the main and earthing circuits to carry the rated peak and the rated short-time withstand current	6 5
d) Tests to verify the making and breaking capacity of the included switching devices	6 101
e) Tests to prove the satisfactory operation of the included switching devices	6 102
f) Tests to verify the protection of persons against contact with live parts and moving parts	6 103
g) Tests to prove the strength of enclosures	6 104
2) *Special type tests* (subject to agreement between manufacturer and user)	
h) Tests to verify the protection of the equipment against external effects due to weather and atmospheric agents	6 105
i) Tests to prove the radio interference voltage (RIV) level	6 2
j) Tests to assess the effects of arcing due to an internal fault	6 106
k) Tests to prove the thermal stability of solid insulation	6 107
l) Tests to prove the satisfactory operation at limit temperatures	6 108
m) Gas tightness tests	6 109

NOTE Some of the type tests may impair the suitability of the tested parts for subsequent use in service

6 1 *Dielectric tests*

6 1 1 *Ambient air conditions during tests*

Refer to 6 1 1 of IEC 694

6.1.2 *Wet test procedure*

Refer to 6.1.2 of IEC 694 with the addition of the following supplement:

A wet test is only necessary for outdoor bushings which have not been tested previously under rain.

For rated voltages of less than 300 kV, the test shall be a power frequency voltage test.

For rated voltages of 300 kV and above, the test shall be a switching impulse voltage test.

The test voltage and the test procedure shall be those specified in IEC 137.

6.1.3 *Conditions of switchgear and controlgear during dielectric tests*

Refer to 6.1.3 of IEC 694 for those items which are applicable.

6.1.4 *Application of test voltage and test conditions*

Subclause 6.1.4 of IEC 694 is not applicable. Because of the great variety of designs, it is not feasible to give specific indication of the tests to be performed on the main circuit, but, in principle, they shall cover the following:

a) To earth and between phases:

The test voltages specified in 6.1.5 shall be applied connecting each phase conductor of the main circuit in turn to the high-voltage terminal of the test supply. All other conductors of the main circuit and the auxiliary circuits are to be connected to the earthing conductor or the frame and to the earth terminal of the test supply.

If an inspection window exists, a dielectric test is made with an earthed metal foil covering the accessible side of the inspection window.

The dielectric tests shall be made with all switching devices (except earthing switches) closed. Attention shall be given to the possibility that switching devices in their open position may result in less favourable field conditions. Under such conditions, the test shall be repeated.

When each phase is individually encased in a metallic enclosure, only tests to earth, and no test between phases, are carried out, unless bushings are used for external connections.

b) Across the open position of switching devices:

Each switching device in the main circuit shall be tested in the open position with the test voltages specified for circuit-breakers, switches or disconnectors in the respective standards related to the rated insulation levels (see 4.2).

If, in the open position of a disconnector, an earthed metallic screen is interposed between the open contacts, this contact gap is not an isolating distance

When voltage or power transformers forming an integral part of the gas-insulated metal-enclosed switchgear have a reduced insulation level, they may be replaced during the dielectric tests by replicas reproducing the field configuration of the high voltage connections Overvoltage protection devices shall be disconnected or removed during the tests

When this procedure is adopted, the voltage or power transformers shall be separately tested in accordance with the relevant standard

6 1 5 *Test voltages*

The rated withstand voltages to earth and between phases (if any) shall be those specified in 4 2 of IEC 694, tables I III and IV

- 72,5 kV to 245 kV in columns (2) and (4),
- 300 kV to 765 kV in columns (2) and (3)

The rated withstand voltages across the isolating distance of disconnectors shall be those specified in IEC 694 for the pertinent rated insulation levels

6 1 6 *Lightning and switching impulse voltage tests*

Refer to 6 1 6 of IEC 694 with the addition of the following supplement

Current transformer secondaries shall be short-circuited and earthed

During the tests, the earthed terminal of the impulse generator shall be connected to the enclosure of the switchgear except that during some of the tests in accordance with item b) of 6 1 4 the enclosure shall, if necessary, be insulated from earth in order that the voltage appearing between any of the live parts and the enclosure will not exceed the test voltage specified in item a) of 6 1 4

6 1 7 *Power-frequency voltage tests on the main circuit*

Refer to 6 1 7 of IEC 694 with the addition of the following supplement

The main circuits of the switchgear shall be subjected to power-frequency voltage tests in dry conditions only

During the tests, one terminal of the test transformer shall be connected to earth and to the enclosure of the switchgear, except that during the tests in accordance with item b) of 6 1 4 the mid-point or another intermediate point of the voltage source should be connected to earth and to the enclosure in order that the voltage appearing between any of the live parts and the enclosure will not exceed the test voltage specified in item a) of 6 1 4

6.1.8 *Artificial pollution tests*

Refer to 6.1.8 of IEC 694 with the addition of the following supplement

These tests apply only to outdoor bushings of gas-insulated metal-enclosed switchgear not previously tested and shall be performed only by special agreement between manufacturer and user

6.1.9 *Partial discharge tests*

The measurement of partial discharges is a suitable means of detecting certain defects in the equipment under test and is a useful complement to the dielectric tests Experience shows that partial discharges may lead in particular arrangements to a degradation in the dielectric strength of the equipment, especially of solid insulation On the other hand it is not yet possible to establish a reliable relationship between the results of partial discharge measurements and the life expectancy of the equipment owing to the complexity of the insulation systems used in gas-insulated metal-enclosed switchgear

The measurement of partial discharges should be made as a type test to show, in correlation with the other dielectric tests, if and where there are weak points with respect to the dielectric stresses resulting from the design of the equipment

The test may be carried out on assemblies or sub-assemblies of the equipment used for all other dielectric tests, and should follow them

The dielectric stresses during the measurement shall, as far as possible, be representative of those which would occur in the complete installation of gas-insulated metal enclosed switchgear.

6.1.9.101 *Test circuits and measuring instruments*

The test circuits and measuring instruments recommended and methods of calibration are given in IEC 270.

A measuring instrument which permits an evaluation of the individual discharges is preferred. Additional information can be gained by measuring the quadratic rate expressed in coulombs squared per second

The elements of the test circuit and the measuring instrument should be chosen so that the minimum measurable discharge intensity is not more than 50 % of the permissible partial discharge intensity

6.1.9.102 *Test procedure*

The applied power-frequency voltage is raised to a pre-stress value U_p and maintained at that value for at least 10 s. Then, the voltage is decreased to the value U_d for measuring the partial discharge intensity.

a) Equipment with single phase enclosures to be used on systems with solidly earthed neutral.

$$U_p = U \qquad U_d = 1,1\ U/\sqrt{3}$$

b) Equipment with three-phase enclosures to be used on systems with solidly earthed neutral.

The test may be made with a three-phase or with a single-phase test circuit.

Three-phase test circuit

The enclosure is connected to the neutral of the voltage supply.

The test voltage is measured between phases.

$$U_p = 1{,}3\ U \qquad U_d = 1{,}1\ U$$

Single-phase test circuit

For the single-phase test the following two methods apply:

1) With the manufacturer's agreement, each phase conductor of the main circuit shall be connected in turn to the voltage supply, the conductors of the other phases being earthed together with the enclosure:

$$U_p = 1{,}3\ U \qquad U_d = 1{,}1\ U$$

2) The test is made with two voltage supplies having one terminal earthed (see figure 1).

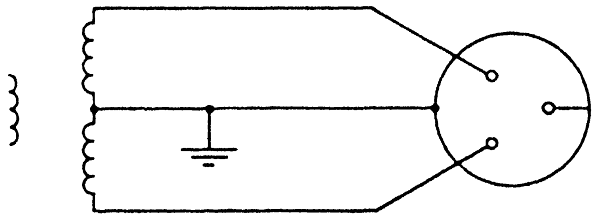


Figure 1

The main supply is connected to one phase conductor; the auxiliary supply is connected to another phase conductor and its voltage shall be chosen so that the voltage between these two phases is equal to $\sqrt{3}$ times the voltage of the main supply. The third phase conductor is connected to the earthed enclosure. The main supply shall be connected to each phase in turn.

The test voltage is measured between the two live phases.

$$U_p = 1{,}3\ U \qquad U_d = 1{,}1\ U$$

c) Equipment with single-phase enclosures to be used on systems without solidly earthed neutral.

$$U_p = 1{,}3\ U \qquad U_d = 1{,}1\ U \qquad \text{and } U_d = 1{,}1\ U/\sqrt{3}$$

d) Equipment with three-phase enclosures to be used on systems without solidly earthed neutral.

The test may be made with a three-phase or with a single-phase test circuit.

Three-phase test circuit

The test voltage is measured between phases

First, the enclosure and the neutral of the voltage supply are earthed, then the enclosure and each phase conductor in turn are earthed

For each case $U_p = 1{,}3\ U$ $U_d = 1{,}1\ U$

Single-phase test circuit

Each phase conductor is connected in turn to the voltage supply, the conductors of the other phases being earthed together with the enclosure

$$U_p = 1{,}3\ U \qquad U_d = 1{,}1\ U \qquad \text{then } U_d = 1{,}1\ U/\sqrt{3}$$

NOTE If possible taking into account the actual background noise level the partial discharge inception and the partial discharge extinction voltages should be recorded as additional information

6 1 9 103 *Maximum permissible partial discharge intensity*

The maximum permissible partial discharge intensity at 1,1 $U/\sqrt{3}$ and at 1 1 U corresponding to the applied test circuit should not exceed the following values

– cast resin insulated bushings and other insulators within the equipment	10×10^{-12} C
– line terminal and transformer bushings	see IEC 137
– voltage transformers having the following types of insulation	
liquid immersed or solid	see IEC 44-4
gas-impregnated paper or synthetic film	10×10^{-12} C

NOTE No separate values are given for current transformers since the designs commonly utilized in gas insulated switchgear do not contain solid primary insulation other than the cast resin insulated bushings

The above values apply to individual components as well as to the sub-assemblies in which they are contained Any sub-assembly containing components with a permitted partial discharge intensity greater than 10×10^{-12} C shall be considered acceptable if the discharge level does not exceed that of the component having the highest permitted discharge intensity

6 1 10 *Dielectric tests on auxiliary circuits*

Refer to 6 1 10 of IEC 694 which is applicable to all low voltage auxiliary circuits

Current transformer secondaries shall be short circuited and disconnected from earth Voltage transformer secondaries shall be disconnected

6.2 *Radio interference voltage (RIV) tests*

Refer to 6.2 of IEC 694 with the addition of the following supplement:

This test is made only if an external bushing exists, and shall be performed by special agreement between manufacturer and user.

6.3 *Temperature-rise tests*

Refer to 6.3 of IEC 694 with the addition of the following supplement:

Where the design provides alternative components or arrangements, the test shall be performed with those components or arrangements for which the most severe conditions are obtained.

The assembly or sub-assembly shall be mounted approximately as in normal service, including all normal enclosures and shall be protected against undue external heating or cooling.

Except in the case when each phase is incased individually in a metallic enclosure, the tests shall be made with the rated number of phases and the rated normal current flowing from one end of the busbars to the terminals provided for the connection of cables.

When a single-phase test is permitted and carried out, the current in the enclosure shall represent the most severe condition.

When testing individual sub-assemblies, the neighbouring sub-assemblies should carry the currents which produce the power loss corresponding to the rated conditions. It is admissible to simulate equivalent conditions by means of heaters or heat insulation, if the test cannot be made under actual conditions.

The temperature rises of the different components shall be referred to the ambient air temperature. They shall not exceed the values specified for them in the relevant standards.

6.4 *Measurement of the resistance of the main circuit*

Refer to 6.4 of IEC 694 with the addition of the following supplement:

The requirements of IEC 694 apply only to the switching devices of gas-insulated metal-enclosed switchgear before and after the temperature-rise test.

In addition, overall measurements are made on transport units in the factory as type test.

6 5 *Short-time and peak withstand current tests*

Refer to 6 5 of IEC 694

6 5 1 *Arrangement of the switchgear and of the test circuit*

Subclause 6 5 1 of IEC 694 is not applicable

Gas-insulated metal-enclosed switchgear with three-phase enclosures shall be tested three-phase Switchgear with single-phase enclosures shall be tested single-phase with the full return current in the enclosure

NOTE Careful attention should be given to the design of enclosures as the arrangement selected may lead to more severe conditions If the enclosure section is not electrically connected to the rest of the switchgear a three phase test should be carried out

6 5 2 *Test current and duration*

Refer to 6 5 2 of IEC 694

6 5 3 *Behaviour of the switchgear during test*

Subclause 6 5 3 of IEC 694 is not applicable

6 5 4 *Conditions of the switchgear after test*

Subclause 6 5 4 of IEC 694 is not applicable

6 5 101 *Tests on the main circuits*

Main circuits of gas-insulated metal-enclosed switchgear shall be tested to verify their capability to withstand the rated short-time and peak withstand current under the intended conditions of installation and use, i e they shall be tested as installed in the switchgear with all associated components influencing the performance or modifying the short-circuit current and according to the standards for the principal switching devices included in the circuits

During these tests, it is necessary to ensure that no overcurrent protection device operates

After the tests, no deformation or damage to components or conductors within the enclosure which may impair good operation shall have been sustained

Short connections to voltage transformers are not considered as parts of the main circuit in this respect

6 5 102 *Tests on earthing circuits*

Earthing circuits of gas-insulated metal-enclosed switchgear which are factory assembled and comprise earthing conductors, earthing connections and earthing devices shall be tested to verify their capability to withstand the rated short-time and peak withstand current under the neutral earthing condition of the system, i e they shall be tested as installed in the switchgear with all associated components which may influence the performance or modify the short-circuit current

After the test, no deformation or damage to the components or conductors within the enclosure which may impair good operation of the main circuit shall have been sustained. Some deformation and degradation of the earthing conductor, earthing connections or earthing devices is permissible, but the continuity of the earthing circuit shall be preserved.

6.101 *Verification of making and breaking capacities*

Switching devices forming part of the main circuit of gas-insulated metal-enclosed switchgear shall be tested to verify their rated making and breaking capacities according to the relevant standards and under the proper conditions of installation and use, i.e. they shall be tested as normally installed in the switchgear with all associated components the arrangement of which may influence the performance, such as connections, supports, etc.

NOTE - In determining which associated components are likely to influence the performance, special attention should be given to mechanical forces due to the short-circuit, to the possibility of disruptive discharges, etc It is recognized that, in some cases, such influences may be quite negligible

For unit tests, see clauses 6 and 7 of IEC 56.

NOTE - Capacitance of the components existing between the terminals of the parts tested and the external connections should be taken into account only for breaking tests

For circuit-breakers using compressed gas, the pressures to be adopted for tests shall be those specified by IEC 56.

6.102 *Mechanical operation tests*

Switching devices of gas-insulated metal-enclosed switchgear shall be submitted to mechanical endurance tests in accordance with their relevant standards, unless previously tested separately.

In addition, all switching devices fitted with interlocks shall be submitted to 50 operating cycles in order to check the operation of the associated interlocks. Before each operation the interlocks shall be set in the position intended to prevent the operation of the switching devices and one attempt shall then be made to operate each switching device. During these tests only normal operating forces shall be employed and no adjustment shall be made to the switching devices or interlocks.

The tests are considered satisfactory if the switching devices and the interlocks are in proper working order and if the forces required to operate the switching devices are practically the same before and after the tests.

The interlocks are considered satisfactory if the switching devices cannot be operated.

6.103 *Verification of the degree of protection for auxiliary circuits and moving parts*

The tests shall be performed in accordance with the requirements specified in clause 7 of IEC 529 for the appropriate first characteristic numeral.

In the case of IP5X no dust shall accumulate in a quantity or in a location such as to interfere with the correct operation of the equipment and no dust shall deposit on the insulations affecting its safe operation.

The tests shall, however, be made only if there are doubts on the compliance with these requirements.

6.104 *Proof tests for enclosures*

Proof tests are made when the strength of the enclosure or parts thereof is not calculated They are performed on individual enclosures before the internal parts are added with testing conditions based on the design pressure stresses.

Proof tests may be either a bursting pressure test or a non-destructive pressure test, as appropriate to the material employed.

6.104.1 *Bursting pressure test*

In the case of a bursting pressure test, the pressure rise should not be faster than 400 kPa/min. The bursting pressure test requirements should be based on 3,5 times the design pressure for cast enclosures and 2,3 times the design pressure for welded enclosures. These factors are based on the minimum certified properties of the material used.

Additional factors may be required taking into account the methods of construction

Any enclosure remaining intact after these pressures have been reached shall be discarded

6.104.2 *Non-destructive pressure test*

In the case of a non-destructive pressure test using a strain indication technique, the following procedure should be applied:

Before the test, strain gauges capable of indicating strains to 0,00005 mm per millimetre shall be affixed to the surface of the enclosure. The number of gauges, their position and their direction shall be chosen so that principal strains and stresses can be determined at all points of importance to the integrity of the enclosure.

Hydrostatic pressure shall be applied gradually in steps of approximately 10 % until the standard test pressure for the expected design pressure (see 7.102) is reached or significant yielding of any part of the enclosure occurs.

When either of these points is reached, the pressure shall not be increased further.

Strain readings shall be taken during the increase of pressure and repeated during unloading

Indication of localized permanent set may be disregarded provided there is no evidence of general distortion of the enclosure.

Should the curve of the strain/pressure relationship show a non-linearity, the pressure may be re-applied not more than five times until the loading and unloading curves corresponding to two successive cycles substantially coincide. Should coincidence not be attained, the design pressure and the test pressure shall be taken from the pressure range corresponding to the linear portion of the curve obtained during the final unloading.

If the standard test pressure is reached within the linear portion of the strain/pressure relationship, the expected design pressure shall be considered to be confirmed.

If the final test pressure or the pressure range corresponding to the linear portion of the strain/pressure relationship (see above) is less than the standard test pressure, the design pressure shall be calculated from the following equation

$$p = \frac{1}{1{,}1\ k} \left(p_y \frac{f_a}{f_t} \right)$$

where

p is the design pressure

p_y is the pressure at which significant yielding occurs or the pressure range corresponding to the linear portion of the strain/pressure relationship of the most highly strained part of the enclosure during final un loading (see above)

k is the standard test pressure factor (see 7 102)

f_t is the permissible design stress at test temperature

f_a is the permissible design stress at design temperature

Alternative procedures for non-destructive pressure tests may be agreed

6 105 *Weatherproofing test*

When agreed between manufacturer and user a weatherproofing test shall be made on gas-insulated metal-enclosed switchgear for outdoor use. A recommended method is given in annex AA. This test also takes into account the effects of wind-driven snow.

If an examination of the design shows the test to be unnecessary, it may be omitted.

6 106 *Test under conditions of arcing due to an internal fault*

If such a test is agreed, the procedure shall be in accordance with the methods described in annex BB

The short-circuit current applied during the arcing test is to be stated by the manufacturer.

Its values should correspond to the rated short-time withstand current or, in some applications of the switchgear in isolated neutral systems, it may be the earth fault current occurring in such a system.

Two assessments are made: the first concerns the performance of the equipment during the operation of the first stage (main) protection and the second concerns the case when the fault is cleared by the operation of the second stage (back-up) protection.

The switchgear should be considered adequate if, during the test, no external effect other than the operation of suitable pressure relief devices occurs within the times specified in 5.103.2 and no fragmentation of the enclosure results from a fault cleared in 0,3 s for currents of 40 kA and above and in 0,5 s for lower currents unless otherwise agreed upon between manufacturer and user.

NOTE - For information, the fault clearing time for the first stage protection is about 0,1 s for currents of 40 kA and above and 0,2 s for lower currents. The time for the second stage protection normally does not exceed 0,3 s for currents of 40 kA and above and 0,5 s for lower currents.

By agreement, tests on a particular arrangement may be used to predict the performance of other arrangements either by calculation or inference or a combination of both.

6.107 *Thermal stability test*

This test is only applicable to parts (such as bushings) of gas-insulated metal-enclosed switchgear, the major insulation of which consists of organic material, having a rated voltage of 145 kV and above and is intended for components filled with a liquid cooling medium the operating temperature of which is between 60 °C and 100 °C.

This test need not be carried out where the electric field in gas or liquid accounts for the major part of the difference in potential between conducting parts.

The test procedure shall be that specified for bushings in IEC 137.

6.108 *Operation tests at limit temperatures*

6.108.1 *Operation test at high temperature*

The switchgear or component tested shall be in the open or in the closed position (this position being stated by agreement between manufacturer and user) in a climatic housing, the temperature of which shall be +40 °C for a duration of five days (120 h).

For two full days, the switching devices shall not be operated.

During one of the last three days, 10 operating cycles are carried out with a frequency of one operating cycle every 4 min.

Towards the end of the test, the following shall be noted:

- the operating times;
- the pressure of the gases contained in the enclosure;
- the gas leakage over a period of 24 h.

It shall be verified that these values remain within the ranges for which the manufacturer guarantees the performance of the switchgear.

During the test, the operation of thermostats, if any, shall also be verified.

6.108.2 *Operation test at low temperature*

This test is identical with the operation test at high temperature, the temperature of the climatic housing being the minimum ambient air temperature specified for normal indoor or outdoor service conditions respectively (see clause 2).

6.109 *Gas tightness tests*

Refer to annex DD.

The measurement of gas tightness shall be performed together with the tests of 6.102 and 6.108 with each type of compartment comprising characteristic sealings of gas-insulated metal-enclosed switchgear as a type test to show that the leakage rate will not be changed by influences caused by the mechanical and limit temperature type tests.

7 Routine tests

The routine tests shall be made with each transport unit and, whenever practicable, at the manufacturer's works to ensure that the product is in accordance with the equipment on which the type test has been carried out.

Refer to clause 7 of IEC 694 with the addition of the following routine tests:

	Subclause
d) Partial discharge measurement:	7.101
e) Pressure tests of enclosures:	7.102
f) Gas tightness tests:	7.103
g) Mechanical operation tests:	7.104
h) Tests of auxiliary electrical, pneumatic and hydraulic devices:	7.105
i) Verification of correct wiring:	7.106

NOTE - It may be necessary to verify the interchangeability of components of the same rating and construction (see clause 5).

7.1 *Power-frequency voltage tests on the main circuit*

Refer to 7.1 of IEC 694 with the addition of the following supplement:

The power-frequency voltage test on the main circuit of gas-insulated metal-enclosed switchgear shall be performed according to the requirements in 6.1.7 to earth, between phases (if applicable) and across the open switching devices. The withstand voltages for routine tests shall be those specified in IEC 694, table I, column 6, table III, column 4, and table IV, column 7, for the respective rated voltages

The tests shall be performed at minimum gas density of the insulating gas

7.2 *Dielectric tests on auxiliary and control circuits*

Refer to 7.2 of IEC 694.

7 3 *Measurement of the resistance of the main circuit*

Refer to 7.3 of IEC 694 with the addition of the following supplement·

Overall measurements are made on transport units in the factory

The overall resistance measured with the switching devices in the closed position shall not exceed 1,2 R_u, where R_u is the sum of the corresponding resistances measured during the type tests.

7.101 *Partial discharge measurement*

The measurement of partial discharges is recommended as a routine test to detect possible material and manufacturing defects. It may also be used as an acceptance test but only if agreed between manufacturer and user

The test may be carried out in accordance with 6.1.9 but only on transport units or components

7.102 *Pressure tests of enclosures*

Pressure tests shall be made on all enclosures after manufacture

The standard test pressure shall be k times the design pressure, where the factor k is.

1,3 for welded enclosures,

1,5 for cast enclosures.

No pressure tests are prescribed after erection on site

7 103 *Gas tightness tests*

Refer to annex DD.

A gas tightness test as agreed between manufacturer and user shall be made to prove compliance of the switchgear with the value of the permissible gas leakage rate prescribed by the manufacturer. If requested, gas tightness tests may be made also across the partitions (see 5.103.3).

NOTE For testing the tightness of a partition, one compartment may be evacuated while the adjacent compartment is filled with gas at the rated density (see 4 101), measuring the pressure rise in the evacuated compartment over a period of 24 h

7.104 *Mechanical operation tests*

Operation tests are made to ensure that the switching devices comply with the prescribed operating conditions and that the mechanical interlocks work properly.

Switching devices of gas-insulated metal-enclosed switchgear shall be submitted to a mechanical routine test in accordance with their relevant standards, unless previously tested separately

In addition, all switching devices fitted with interlocks shall be submitted to five operating cycles in order to check the operation of the associated interlocks Before each operation one attempt shall be made to operate each switching device as specified in 6.102

During these tests, which are performed without voltage on or current in the main circuits, it shall be verified in particular that the switching devices open and close correctly within the specified limits of the supply voltage and pressure of their operating devices.

7 105 *Tests of auxiliary electrical, pneumatic and hydraulic devices*

The electrical, pneumatic and other interlocks together with control devices having a predetermined sequence of operations shall be tested five times in succession in the intended conditions of use and operation and with the most unfavourable limit values of auxiliary supply During the test no adjustment shall be made.

The tests are considered to be satisfactory, if the auxiliary devices have operated properly, if they are in good operating condition after the tests and if the force to operate the switching device is practically the same before and after the tests.

7.106 *Verification of the correct wiring*

It shall be verified that the wiring conforms with the diagram and the prescribed requirements.

7 107 *Tests after erection on site*

After erection, before putting into service, the gas-insulated metal-enclosed switchgear shall be tested to check the correct operation and the dielectric strength of the equipment.

These tests and verifications comprise

	Subclause
a) Voltage tests on the main circuits	7 107 1
b) Dielectric tests on auxiliary circuits	7 2
c) Measurement of the resistance of the main circuit	7 107 4
d) Gas tightness tests	7 103
e) Checks and verifications	7 107 2
f) Measurement of gas condition	7 107 3

For reasons given in 5 103 1 and to ensure minimum disturbance, and to reduce the risk of moisture and dust entering enclosures so preventing correct operation of the switch gear, no obligatory periodic inspections or pressure tests are specified or recommended when the gas-insulated substation is in service

A test should be made to prove the absence of dangerous circulating currents in the enclosure and other metallic parts, such as pipes and supporting structures, if these are not intended for such currents

7 107 1 *Voltage tests on the main circuits*

7 107 1 1 *General*

Since it is exceptionally important for this kind of switchgear, the dielectric strength shall be checked in order to eliminate fortuitous causes (wrong fastening, damage during handling, transportation, storage and erection, presence of foreign bodies etc) which might in the future give rise to an internal fault

Because of their different purpose, these tests shall not replace the type tests or the routine tests carried out on the transport units and, as far as possible, in the factory They are supplementary to the dielectric routine tests with the aim of checking the dielectric integrity of the completed installation and of detecting irregularities as mentioned above Normally the dielectric test shall be made after the switchgear has been fully erected and gas-filled at the rated density preferably at the end of all site tests, when newly installed Such a dielectric test is recommended to be performed also after major dismantling for maintenance or reconditioning of compartments These tests are to be distinguished from the progressive voltage increase performed in order to achieve a kind of electrical conditioning of the equipment before commissioning

The execution of such site tests is not always practicable and deviations from the standards may be accepted The aim of these tests being a final check before energizing It is very important that the chosen test procedure does not jeopardize sound parts of the switchgear

In choosing an appropriate test method for each individual case a special agreement may be necessary in the interest of practicability and economy, e g the electrical power requirements, and the dimensions and weight of the test equipment may need to be considered

A detailed test programme for the dielectric tests on site shall be agreed between manufacturer and user.

7.107.1.2 *Test procedure*

The switchgear shall be erected completely and gas-filled at its rated density.

Some parts may be disconnected for the test, either because of their high charging current or because of their effect on voltage limitation, such as:

- high voltage cables and overhead lines;
- power transformers and most voltage transformers;
- surge arresters and protective spark gaps.

NOTES

1 In determining the parts which could be disconnected attention is drawn to the fact that the reconnection may introduce faults after the tests are finished

2 In order to test as much as possible of the switchgear, a removable link may be included in the design in each of the above-mentioned cases Here a "link" is understood to be a part of the conductor which can easily be removed in order to isolate two parts of the switchgear from each other This type of separation is preferable rather than dismantling

Every newly erected part of gas-insulated metal-enclosed switchgear shall be subjected to a dielectric test on site.

In the case of extensions, in general, the adjacent existing part of the switchgear should be de-energized and earthed during the dielectric test, unless special measures are taken to prevent disruptive discharges in the extension affecting the energized part of the existing switchgear.

Application of the test voltage may be necessary after repair or maintenance of major parts or after erection of extensions. The test voltage may then have to be applied to existing parts in order to test all sections involved. In those cases the same procedure should be followed as for newly erected switchgear.

7.107.1.3 *Voltage waveforms*

For the choice of an appropriate voltage waveform, IEC 60-2 should be taken into consideration, however, similar waveforms are also permissible. An ideal voltage waveform covering all requirements does not exist. Permissible deviations are indicated below. Information concerning the generation of test voltages is given in clause CC1 of annex CC.

1) *A.C. voltage tests*

A.C. voltage tests are especially sensitive in detecting contaminations (e.g. conducting particles), and are in most cases also sufficient in detecting abnormal field configurations.

The existing experience refers to test frequencies of 50 Hz and 60 Hz. The test frequency should be limited to the range of 10 Hz to 300 Hz.

NOTE - Attention should be given to the fact that for voltage tests with frequencies other than the rated frequencies of 50 Hz and 60 Hz further experience with such tests has to be taken into account

2) *Impulse voltage tests*

a) Tests with lightning impulse voltages are especially sensitive in detecting abnormal field configurations (e.g. damaged electrodes).

Based on the existing experience, lightning impulse voltages with a front time extended up to 8 µs are acceptable. When using oscillating lightning impulse voltages the front time may be extended to approximately 15 µs.

NOTE - Reflections due to steep front waves in large installations should be taken into account

b) Tests with switching impulse voltages are useful especially for higher rated voltages to detect the presence of contaminations as well as abnormal field configurations with relatively simple test equipment.

Based on existing experience, switching impulses with either aperiodic or oscillating waveforms and with a time to crest in the range of 150 µs to 10 ms are suitable.

3) *D.C. voltage tests*

A d.c. voltage test cannot be recommended. The existing test specifications for cables are not applicable to gas-insulated metal-enclosed switchgear (refer to 5.109).

7.107.1.4 *Test voltages*

Considering that:

- transport units have normally been subjected to routine tests;
- the probability of disruptive discharges is higher for the complete installation than for individual functional units;
- disruptive discharges in correctly erected equipment shall be avoided;

the test voltage for dielectric tests on site shall be:

- 80 % of the a.c. voltage applied for the routine test;
- 80% of the voltage applied for lightning and switching impulse tests.

Where no switching impulse voltage is specified, the value of the switching impulse voltage for dielectric tests on site shall be 80 % of the lightning impulse test voltage on site.

NOTE - Special attention should be given to the relative severity of non-standardized waveforms the test voltage value of which should be adjusted accordingly.

In certain circumstances, for technical or practical reasons, dielectric tests on site may be carried out with reduced voltage values. Details are given in clause CC3 of annex CC.

7.107.1.5 *Dielectric test procedures*

The test procedure should be agreed between manufacturer and user and be chosen from:

Procedure A

A.C. voltage test for a duration of 1 min at the specified value.

In special cases this test may be complemented by an impulse voltage test consisting of three impulses of each polarity at the specified value.

Procedure B

A.C. voltage test for a minimum duration of 5 min at a value not lower than $U/\sqrt{3}$ for earthed neutral or U for isolated neutral or resonant earthed systems. This test is followed by an impulse voltage test consisting of three impulses of each polarity at the specified value.

Other tests may be acceptable based on service experience and the results of further development (see clause CC3 of annex CC).

7.107.1.6 *Voltage application*

The specified test voltage shall be applied between each phase conductor, one at a time, and the enclosure, the other phase conductors being connected to the earthed enclosure. The insulation between phase conductors shall not be subjected to any other separate dielectric test on site.

The test voltage source may be connected to any convenient point of the phase conductor under test.

It is often convenient to divide the whole installation of gas-insulated metal-enclosed switchgear into sections by opening circuit-breakers and disconnectors for at least one of the following reasons:

- to facilitate the location of disruptive discharges;
- to limit the discharged energy if a disruptive discharge occurs;
- to limit the capacitive load on the test voltage source.

The sections which in such cases are not being tested and which are isolated by a circuit-breaker or a disconnector from the section under test shall be earthed. Unless dismantled after routine test, no dielectric test across the open switching devices need be carried out on site.

7.107.1.7 *Assessment of the test*

The switchgear shall be considered to have passed the test, if each section has withstood the specified test voltage without any disruptive discharge.

In the event of a disruptive discharge occurring during dielectric tests on site, steps shall be taken to ensure the dielectric strength of the equipment. This may be achieved either by the inspection of the solid insulation, if practicable and if the location of the disruptive discharge is known (see clause CC2 of annex CC), or it may be done by performing additional dielectric tests according to an agreement between manufacturer and user established before the site tests have started.

Guidelines on repetition tests are given in clause CC6 of annex CC.

7.107.2 *Checks and verifications*

The following shall be verified:

a) conformity of the assembly with the manufacturer's drawings and instructions;

b) sealing of all pipe junctions, and the tightness of bolts and connections;

c) conformity of the wiring with the diagrams;

d) proper function of the electrical, pneumatic and other interlocks;

e) proper function of the control, measuring, protective and regulating equipment including heating and lighting.

NOTE - If for whatever reasons one or more routine tests are not performed at the manufacturer's works, they should be carried out on site combined with the tests after erection.

7.107.3 *Measurement of gas condition*

The moisture content of the insulating gas shall be determined. The content shall not exceed the maximum limit permitted by the manufacturer.

If the switchgear is filled with sulphur hexafluoride, for checking the condition of the gas during service, reference is made to IEC 480.

7.107.4 *Measurement of the resistance of the main circuit*

Overall measurements shall be made on the complete installation, under conditions as similar as possible to those of the routine test on transport units.

The resistances measured shall not exceed the maximum values permitted for the routine tests on transport units (see 7.3), taking into account the differences of the two test arrangements (number of devices, contacts and connections, length of conductors, etc.).

8 Guide to the selection of the switchgear for service

For a given duty in service, gas-insulated metal-enclosed switchgear is selected by considering the individual rated values of its components required under normal load conditions and in case of fault conditions.

The rated values should be chosen as suggested in this standard regarding the characteristics of the system as well as its expected future development. The complete list of rating is given in clause 4.

For external insulation only, other parameters such as local atmospheric and climatic conditions and the use at altitudes exceeding 1 000 m are to be considered (see clause 2).

The duty imposed by fault conditions should be determined by calculating the fault currents at the place where the switchgear is to be located in the system.

9 Information to be given with enquiries, tenders and orders

9.101 *Information with enquiries and orders*

When enquiring for or ordering an installation of gas-insulated metal-enclosed switchgear the following information should be supplied by the enquirer:

1) *Particulars of the system*

Nominal and highest voltage, frequency, type of system neutral earthing.

2) *Service conditions*

Minimum and maximum ambient air temperature; any condition deviating from the normal service conditions or affecting the satisfactory operation of the equipment, for example, unusual exposure to vapour, moisture, fumes, explosive gases, excessive dust or salt, the risk of earth tremors or other vibrations due to causes external to the equipment to be delivered, as well as possible movements of foundations.

3) *Particulars of the installation and its components*

a) indoor or outdoor installation;
b) number of phases (individually encased or in a common enclosure);
c) number of busbars;
d) rated voltage;
e) rated insulation level;
f) rated normal currents of busbars and feeder circuits;
g) rated short-time withstand current (I_{th});
h) rated duration of short-circuit (if different from 1 s);
i) rated peak withstand current (if different from 2,5 I_{th});
j) rated values of components;
k) degree of protection for auxiliary circuits and moving parts;
l) circuit diagrams;
m) details of high-voltage cable connections.

4) *Particulars of the operating devices*
   - a) type of operating devices;
   - b) rated supply voltage (if any);
   - c) rated supply frequency (if any);
   - d) rated supply pressure (if any);
   - e) special interlocking requirements.

In addition to these items, the enquirer should indicate every condition which might influence the tender or the order, as, for example, special mounting or erection conditions, the locating of the external high-voltage connections or the rules for pressure vessels.

Information should be supplied if special type tests are required.

9.102 *Information with tenders*

The following information, if applicable, should be given by the manufacturer with descriptive matters and drawings:

1) *Rated values and characteristics*

Particulars of the installation are enumerated in section 3) of 9.101.

2) *Further particulars of the switchgear and its components*
   - a) design pressure of enclosures;
   - b) design temperature of enclosures;
   - c) type and rated density of gas for insulation;
   - d) minimum gas density;
   - e) volume of gas for the different compartments;
   - f) limit values of moisture content and gas leakage;
   - g) details of appropriate measures for fault location.

3) *Type test certificates or reports*

When certificates are requested, in general the first pages containing the results may be sufficient.

4) *Constructional features*
   - a) mass of the heaviest transport unit;
   - b) overall dimensions of the switchgear;
   - c) arrangement of the external connections;
   - d) provisions for transport to be taken by the user;
   - e) provisions for mounting to be taken by the user.

5) *Particulars of the operating devices*
   - a) types and rated values as enumerated in section 4) of 9.101;
   - b) current or power for operation;
   - c) operating times;
   - d) quantity of free gas for operation.

6) *Information about all matters to be subject to prior agreement between manufacturer and user*

7) *List of recommended spare parts*

Spare parts should be procured by the user.

8) *Instructions for operation and maintenance.*

10 Rules for transport, storage, erection and maintenance

Refer to clause 10 of IEC 694.

10.1 *Conditions during transport, storage and erection*

Refer to 10.1 of IEC 694.

10.2 *Erection*

Refer to 10.2 of IEC 694.

10.3 *Maintenance*

Refer to 10.3 of IEC 694.

Annex AA
(normative)

Recommended method for the weatherproofing test for outdoor gas-insulated metal-enclosed switchgear

The gas-insulated metal-enclosed switchgear to be tested shall be fully equipped and complete with all top covers, screens, bushings, etc , and placed in the area to be supplied with artificial precipitation

The artificial precipitation shall be supplied by a sufficient number of nozzles to produce a uniform spray over the surfaces under test The various parts of the equipment may be tested separately, provided that a uniform spray is simultaneously applied also to both of the following

a) the top surfaces from nozzles located at a suitable height,

b) the floor for a distance of 1 m in front of the parts under test with the equipment located at the minimum height above the floor level specified by the manufacturer

Where the width of the equipment exceeds 3 m, the spray may be applied to 3 m wide sections in turn Pressurized enclosures need not be submitted to artificial precipitation

Each nozzle used for this test shall deliver a square-shaped spray pattern with uniform spray distribution and shall have a capacity of 30 l/min ± 10 % at a pressure of 4,6 bar ± 10 % and a spray angle of 60° to 80° The centre lines of the nozzles shall be inclined downwards so that the top of the spray is horizontal if it is directed towards the surfaces being tested It is convenient to arrange the nozzles on a vertical stand-pipe and space them about 2 m apart (see test arrangement in figure AA1)

The pressure in the feedpipe of the nozzles shall be 4,6 bar ± 10 % under flow conditions The rate at which water is applied to each surface under test shall be about 5 mm/min, and each surface so tested shall receive this rate of artificial precipitation for a duration of 5 min The spray nozzles shall be at a distance between 2,5 m and 3 m from the nearest vertical surface under test

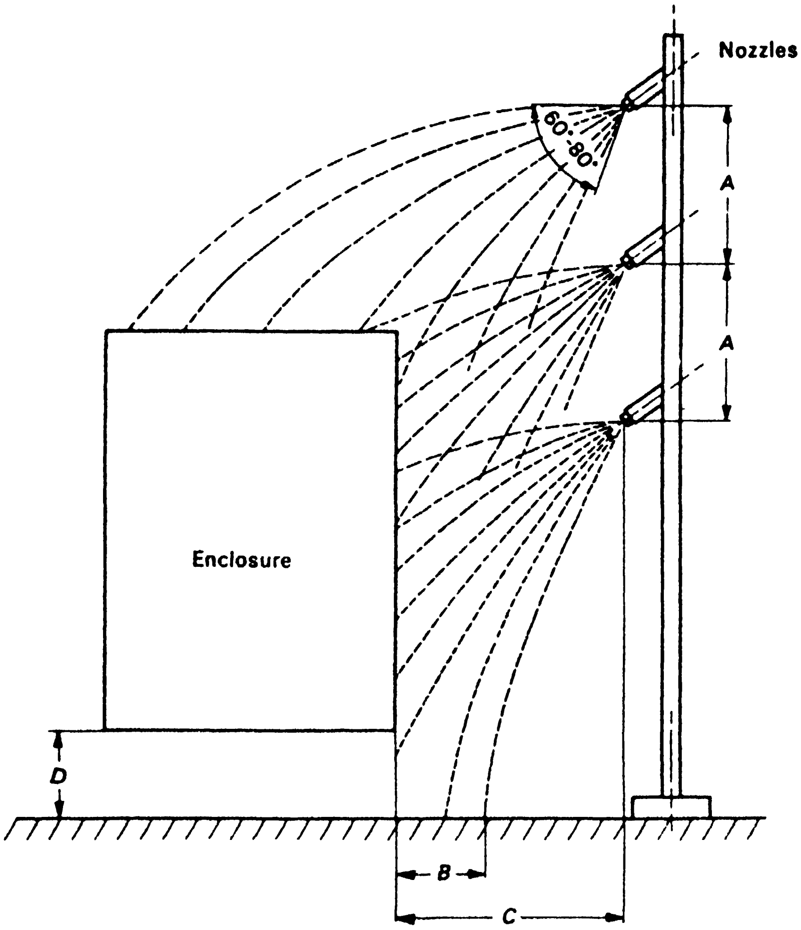
NOTE - When a nozzle in accordance with figure AA2 is used the quantity of water is considered to be in accordance with this standard when the pressure is 4 6 bar ± 10 %

After the test is completed, the equipment shall be inspected promptly to determine whether the following requirements have been met

a) no water shall be visible on the insulation of the auxiliary circuits,

b) no water shall be visible on electrical components or mechanisms of the equipment except for bushings,

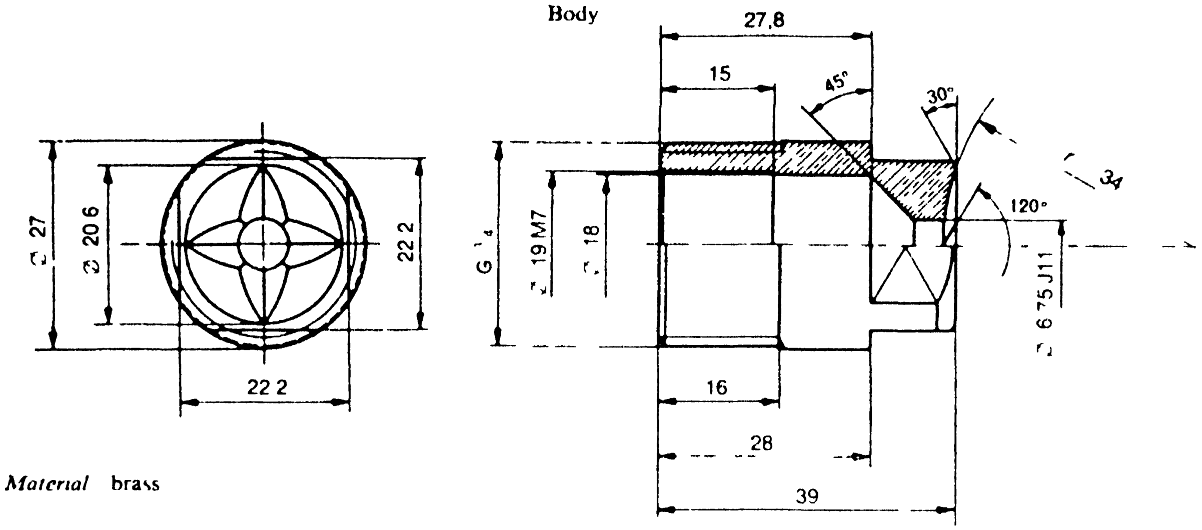
c) no significant accumulation of water shall be retained by the structure or other non insulating part (to minimize corrosion)



A	About 2 m
B	About 1 m
C	2,5 m to 3 m

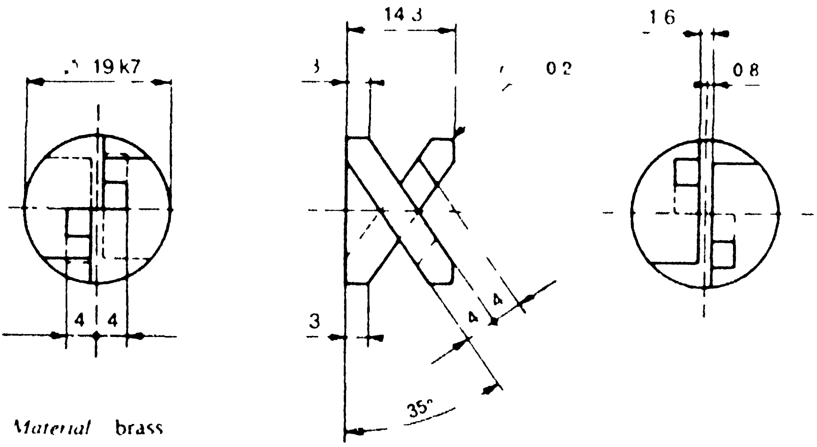
Figure AA1 – Arrangement for the weatherproofing test

Body

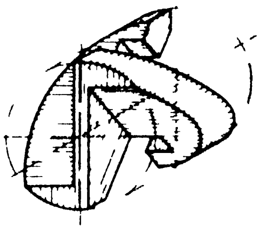


Material brass

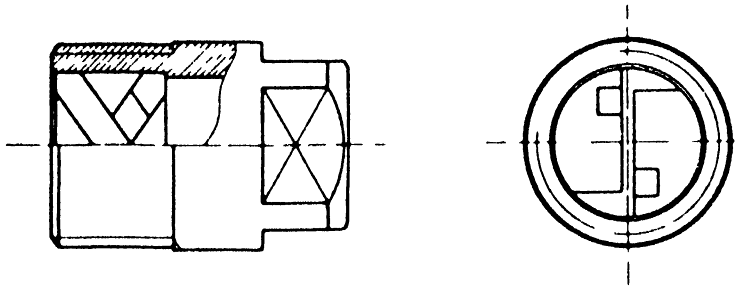
Internal vanes



Material brass



Assembly



Scale 1:1

Dimensions in millimetres

Figure AA 2 – Example of a nozzle meeting the requirements of the weatherproofing test

Annex BB
(normative)

Methods for testing gas-insulated metal-enclosed switchgear under conditions of arcing due to an internal fault

BB1 Introduction

The occurrence of an arc inside gas-insulated metal-enclosed switchgear due to an internal fault is accompanied by various physical phenomena.

For example, the energy resulting from an arc developing in the enclosure will cause internal overpressure and local overheating, which will result in mechanical and thermal stressing of the switchgear. Moreover, the materials involved may produce hot decomposition products which may be discharged into the atmosphere.

This annex takes into account the internal overpressure acting on the enclosure and the thermal effects of the arc or its root on the enclosure. It does not cover all the effects which may constitute a risk, such as toxic gases.

BB2 Short-circuit current arcing test

BB2.1 *Test arrangements*

When choosing the object to be tested, reference should be made to the design documents for the switchgear. The compartments which appear to have the least likelihood of withstanding the pressure and temperature rise in the event of arcing should be selected.

In any case, the following points should be observed:

a) Each test may be carried out on a test object not previously subjected to arcing tests. Test objects that have already undergone arcing tests should be restored so that the conditions for further arcing tests are neither aggravated nor eased.

b) The test object shall be fully equipped and arranged to include any protection device, such as pressure reliefs, short-circuiting devices, etc., provided by the manufacturer for the limitation of the effects of the arc.

"Mock-ups" are permitted provided they have the same volume and external material and would react in the same way as the original parts with respect to withstanding arcing.

c) The test object should be filled with normal insulating gas at rated density.

BB2.2 *Current and voltage applied*

Single-pole enclosures should be tested single-phase, and three-pole enclosures should be tested three-phase.

BB2.2 1 *Voltage*

The test can be made with an applied voltage lower than the rated voltage of the test object if the following conditions are met

a) the arc current shall be practically sinusoidal,

b) the arc shall not extinguish prematurely

BB2 2 2 *Current*

1) *A C component*

The a c component at the beginning of the test should lie within a +10 % and 0 % tolerance Within the duration of the first stage protection, the tolerance should be ±10 % and within the duration of the second stage protection the current should not fall below 80 % of the specified value provided that the average a c component is not less than the stated short-circuit current

NOTE If the test plant does not permit this the test duration may be extended by not more than 20% with an appropriate adjustment to the times at which assessments are made

2) *D C component*

The instant of short-circuit making should be chosen to ensure that the first loop of the arc-current has a peak value of at least 1,7 times the r m s value of the stated short-circuit current a c component For three-phase tests, this applies to the current in at least one phase

BB2 2 3 *Frequency*

For 50 Hz or 60 Hz rated frequency, the frequency at the beginning of the test should lie within the limits of 48 Hz and 62 Hz

For 16 2/3 Hz or 25 Hz rated frequency, it is permissible to make tests with 25 Hz with a tolerance of ±10 % The frequency at the beginning of the test may also lie within the limits of 48 Hz and 62 Hz, if the test duration is at least 0,1 s

BB 2 2 4 *Duration of the test*

The current duration shall be such as to cover the second stage protection chosen on the basis of the expected duration as determined by the protection devices

BB2 3 *Test procedure*

BB2 3 1 *Test connections*

The point of current infeed to be chosen is the one likely to result in the most onerous condition

Care should be taken in order that the connections do not ease the test conditions Generally, the enclosure is earthed on the same side of the test object into which the current is fed

BB2.3.2 *Arc initiation*

The arc should be initiated by means of a metal wire of suitable diameter

The point of initiation to be chosen is where the arc is likely to set up the highest stresses in the test object Generally, this will be achieved when the arc is initiated in the vicinity of a barrier furthest from the point of infeed and the pressure relief device, if fitted.

NOTE - The arc should not be initiated by perforating the solid insulation

BB2.3.3 *Measurement and recording of the test performance*

The following parameters should be plotted and recorded:

- the current and its duration;
- the arc voltage;
- the pressure on one or more points of the test object; in each compartment, if the test object comprises more than one,

and, when applicable,

- the instant of pressure relief (either by operation of the pressure relief device or perforation of the enclosure).

Phenomena such as pressure relief, enclosure perforation and external effects should be observed and recorded by appropriate means, e.g. cameras, luminosity detectors.

BB2.4 *Assessment of the test*

The switchgear is considered adequate if, during the test, no external effect other than the operation of suitable pressure relief devices occurs within the times specified in 5.103.2 and if gases or vapours escaping under pressure are directed so as to minimize the danger to an operator performing his normal operating duties.

No fragmentation of the enclosure shall result from a fault cleared in 0,3 s for currents of 40 kA and above and in 0,5 s for lower currents.

BB2.5 *Test report*

The following information should be given in the test report:

- rating and description of the test object, the materials of the enclosure and the conductors, together with a drawing showing the main dimensions and the arrangement of pressure relief devices;
- arrangement of the test connections, the point of initiation of the arc and the position of the transducers for pressure measurements;
- currents, voltages, energies, pressures and times derived from the oscillograms;
- precise description of the test results and observations;
- other relevant remarks;
- photographs of the conditions before and after the test.

BB2.6 *Extension of the test results*

To extend the test results to other enclosures of similar design but of different size and shape and/or to other test parameters, calculation methods may be agreed between manufacturer and user.

BB3 Composite verification by calculation and separate tests

Under consideration.

Annex CC
(informative)

Technical and practical considerations of site testing

CC1 Test voltage generators

Load capacitances of gas-insulated metal-enclosed switchgear installations are relatively high, this means that:

- a.c. voltage tests especially at higher rated voltages require a high reactive power;

- impulse testing with standardized double exponential waveforms may be inefficient due to the poor voltage utilization of the impulse generator.

The following voltage generating equipment may be used:

1) *A.C. voltage sources*

The a.c. voltage may be produced by:

- test sets with a test transformer;
- test sets with a variable resonant reactor for constant frequency;
- test sets with a constant resonant reactor for variable frequency;
- energizing power or voltage transformers from the low-voltage side which entails no dismantling after testing.

NOTE - The thermal stresses of the voltage source should be taken into account especially when using voltage transformers

2) *Impulse voltage sources*

For large installations and especially for high rated voltages, impulse generators for double exponential waves are unwieldy. Oscillating impulses may be produced with an impulse generator and a high-voltage coil connected to the switchgear to be tested to form a damped series resonant circuit. Oscillating switching impulses may be produced by discharging a capacitor into the low-voltage side of a power, voltage or test transformer

CC2 Locating discharges

There are different phenomena caused by discharges which may be helpful in locating them. Some of the possible means which may be tried are as follows:

- detection of light emission;
- measurement of audible noise and vibrations;
- recording and evaluation of electromagnetic transients following discharge,

- chemical analysis of decomposition products of the gas.

CC3 Special test procedures

In general, it is recommended that all testing should be performed at the specified test voltage and rated gas density. However, in certain circumstances special test procedures have been established which are not in general use but are worth mentioning for technical and/or practical reasons.

CC3.1 *Testing at reduced voltage*

CC3.1.1 *Simplified method for units transported without dismantling*

In accordance with the practice in some countries gas-insulated metal-enclosed switchgear, or at least one bay or an equivalent part of the switchgear installation, may be assembled completely at the factory and tested there at its full rated withstand voltages. If the tested units are transported without dismantling or if dismantling is limited to very simple connections, and subject to agreement between manufacturer and user, the site test may be reduced to the following:

- a.c. voltage test with 1,1 $U/\sqrt{3}$ for earthed neutral systems or 1,9 $U/\sqrt{3}$ for isolated neutral or resonant earthed systems; the time of voltage application shall be 10 min.

CC3.1.2 *Deviations due to practical needs*

In certain circumstances due to technical or practical reasons, an a.c. voltage test may be performed at reduced voltage and for an extended duration, subject to agreement between manufacturer and user.

CC3.1.3 *Application of service voltage*

In some cases, it is impracticable to perform a dielectric test on site. Then special care should be taken for shipment, transportation and storage and particular attention should be given to the workmanship on site. The switchgear to be tested should be energized by the service voltage through the largest possible impedance in order to reduce damage caused by a possible disruptive discharge. The test period should be at least 30 min.

CC3.2 *Testing at reduced gas density*

Tests with reduced gas density are not generally advisable.

CC4 Partial discharge measurements

Partial discharge measurements may be helpful in detecting certain kinds of faults during site tests and in determining the need for maintenance of the equipment after a period in service. They are therefore a useful complement to dielectric tests on site but are often difficult to perform because of ambient disturbances.

If such a test is possible and agreed the requirements given in 6 1 9 should be applied as far as possible The measurements should be made at 1,1 $U/\sqrt{3}$ after the power-frequency voltage test, and at $U/\sqrt{3}$ for comparison with future measurements in service when suitable systems have been developed The particulars of partial discharge measurements on site are under consideration

CC5 Electrical conditioning

The term "electrical conditioning" means a progressive application of an a c voltage either by steps or continuously It may be performed by the manufacturer as part of the gas-filling process on site in order to move possible particles towards areas with a low field strength, where they become harmless

Electrical conditioning is not a requirement and does not replace the a c voltage test unless the test voltage is increased up to the specified value Nevertheless, a disruptive discharge should be reported to the user as it may result in a weakening of the insulation

CC6 Repetition tests

CC6 1 *General*

The procedure to be implemented following a disruptive discharge during dielectric tests on site may depend on several factors which include

- kind of disruptive discharge (breakdown in self-restoring or non-self-restoring insulation) if it can be identified (see clause CC2)
- magnitude of the arc energy dissipated during the discharge,
- shape and material of the solid insulation
- strategic importance of the installation

Consideration of these and any other relevant factors should allow a procedure to be established and agreed between manufacturer and user A recommended procedure is given below but should be treated only as a guide and variations may be acceptable depending on the significance of the factors involved

CC6 2 *Recommended procedure*

a) If the disruptive discharge occurs along the surface of a solid insulation it is recommended that wherever practicable the compartment should be opened and the insulation carefully inspected for impairments After taking any necessary remedial action the compartment should then be subjected to the specified dielectric test once more

b) A disruptive discharge in the gas may be due to contamination or a surface imperfection which may be burned away during the discharge It may be acceptable therefore that the test may be repeated at the specified test voltage Another test voltage may be agreed between manufacturer and user before the site tests have been started

NOTE It is assumed that the manufacturer can satisfy the user that the gaseous insulation may be regarded as self restoring for the arc energy dissipated in the discharge

If the repetition test fails again the procedure of item a) should be followed

Annex DD
(normative)

Gas tightness specifications and tests

Introduction

This annex DD is derived from a corresponding Appendix EE of IEC 56 (1987). At the TC 17 meeting in Helsinki (October 1987) it was decided to transfer gas tightness specifications and tests as a common clause to IEC 694 on the occasion of a future revision. Meanwhile the annexes shall be retained or introduced in the relevant standards (IEC 56; IEC 517; IEC 298).

The annex DD has been adapted to the conditions of gas-insulated metal-enclosed switchgear as far as necessary. Other modifications, e.g. to delete definitions which are not relevant to this standard or to transfer definitions from the annex to the standard itself, have not been implemented in order to preserve the common character of the annex and thus to facilitate a later transfer to IEC 694.

DD1 Scope and object

This annex applies to gas-insulated metal-enclosed switchgear which uses gas, other than air at atmospheric pressure, as insulating or combined insulating and interrupting medium. Its purpose is to define characteristics and test procedures relative to gas tightness.

DD2 Definitions

DD2.1 *Controlled pressure system*

An assembly which is automatically refilled from an external or internal gas source.

DD2.2 *Closed pressure system*

An assembly which is refilled only periodically by manual connection to an external gas source.

DD2.3 *Sealed pressure system*

An assembly for which no further gas processing is required during its expected operating life.

NOTE - Sealed pressure systems are completely assembled and tested in the factory.

DD2.4 *Rated filling pressure, P_r (or density D_r)*

The pressure in bars (gauge) referred to the standard atmospheric air conditions of 20 °C and 1 013 hPa (or density) to which the assembly is filled before being put into service or automatically refilled

DD2.5 *Minimum functional pressure, P_m (or density D_m)*

The gas pressure in bars (gauge) referred to the standard atmospheric air conditions of 20 °C and 1 013 hPa (or density) at and above which the rated values of the switchgear are maintained and at which refilling becomes necessary

DD2.6 *Absolute leakage rate, F*

The amount of gas escaped by time unit, expressed in bar cm³/s at atmospheric pressure 1 013 hPa

DD2 7 *Permissible leakage rate, F_p*

The maximum permissible leakage rate specified by the manufacturer for a part, or a component, or a sub-assembly, or, by using the tightness coordination chart *TC*, for an arrangement of parts, components or sub-assemblies connected together in one pressure system

DD2.8 *Relative leakage rate, F_{rel}*

The absolute leakage rate related to the total amount of gas in the system at rated filling pressure (or density)

It is expressed in percentage per year or per day

DD2.9 *Time between refillings, T*

The time elapsed between two refillings performed either manually or automatically to compensate the leakage rate *F*.

DD2.10 *Number of refillings per day, N*

The number of refillings to compensate the leakage rate *F*.

This value is applicable to controlled pressure systems

DD2.11 *Pressure drop, ΔP*

The drop of pressure in a given time caused by the leakage rate F, without refilling.

DD2.12 *Tightness coordination chart, TC*

A survey document supplied by the manufacturer, used when testing parts, or components, or sub-assemblies, to demonstrate the relationship between the tightness of a complete gas system and that of parts, components and/or sub-assemblies.

DD2.13 *Cumulative leakage measurement*

A measurement which takes into account all the leaks from a given assembly to determine the leakage rate.

DD2.14 *Sniffing*

The action of slowly moving a leakmeter sensing probe around an assembly to locate a leak.

DD3 Specifications for gas tightness

DD3.1 *Controlled pressure systems*

The tightness of controlled pressure systems is specified by the number of refillings per day (N) or by the pressure drop per day (ΔP). The permissible values shall be given by the manufacturer.

DD3.2 *Closed pressure systems*

The tightness of closed pressure systems is specified by two quantities:

- relative leakage rate F_{rel};
  preferred values are 1 % and 3 % per year;
- time between refillings T;
  preferred values are 3 years and 10 years.

DD3.3 *Sealed pressure systems*

The tightness of sealed pressure systems is specified by their expected operating life. Preferred values are 10 years, 20 years and 30 years.

DD4 Tests

The purpose of tightness tests is to demonstrate that the total system leakage rate F does not exceed the specified value F_p

If possible, the tests should be performed on a complete installation at P_r (or D_r) If this is not practical, the tests may be performed on parts, components or sub-assemblies In such cases, the leakage rate of the total system shall be determined by summation of the component leakage rates using the tightness coordination chart *TC* (see figure DD1)

The tightness test of the enclosure containing a mechanical switching device shall be measured both in the closed and open positions of this device, unless the leakage rate is independent of the position of the main contacts

By agreement between the manufacturer and the user the leakage between compartments may also be determined

In general, only cumulative leakage measurements allow calculation of leakage rates

The type test report should include such information as

- a description of object under test including its internal volume and the nature of the filling gas,
- whether the object under test is in the closed or open position (if applicable)
- the pressures and temperatures recorded at the beginning and end of the test and the number of refillings,
- the cut in and cut off pressure settings of the pressure (or density) control or monitoring device,
- an indication of the calibration of the meters,
- the results of the measurements
- if applicable, the test gas and the conversion factor to assess the results

DD4 1 *Type tests of pressure systems*

The tightness test shall be performed before and after the mechanical operation test and during the operation tests at limit temperatures (see 6 102 and 6 108)

An increased leakage rate at extreme temperatures (if such tests are required in the relevant standards) and/or during operations is acceptable, provided that this rate resets to the initial value after the temperature is returned to normal ambient air temperature and/or after the operations are performed The increased temporary leakage rate shall not exceed three times the specified permissible value F_p

a) *Controlled pressure systems*

The relative leakage rate F_{rel} shall be checked by measuring the pressure drop ΔP over a time period t that is of sufficient length to permit a determination of the pressure drop (within the filling and refilling pressure range) A correction should be made to take into account the variation of ambient air temperature During this period the refilling device shall be inoperative

$$F_{rel} = \frac{\Delta P}{P_r} \times \frac{24}{t} \times 100 \text{ (\% per day)}$$

$$N = \frac{\Delta P}{P_r - P_m} \times \frac{24}{t}$$

t = test duration (hours)

Alternatively, the number of refilling operations per day may be measured directly.

b) *Closed pressure systems and sealed pressure systems*

Due to comparatively small leakage rates of these systems, pressure drop measurements are not applicable. Other methods (examples are given in Figure DD2) may be used to measure the leakage rate F, which is used in combination with the tightness coordination chart to calculate:

- the relative leakage rate F_{rel} and the time between refillings T for closed pressure systems;
- the expected operating life for sealed pressure systems.

If the test object is filled with a test gas different to the gas used in service and/or at a test pressure different to the normal operating pressure, corrective factors defined by the manufacturer shall be used for calculations.

NOTE - Leakage rate measurements in practice may have an inaccuracy of ±50 %.

DD4.2 *Routine tests of pressure systems*

Routine tests shall be performed at normal ambient air temperature with the assembly filled at the pressure (or density) corresponding to the manufacturer's test practice. Sniffing may be used under controlled conditions:

a) *Controlled pressure systems*

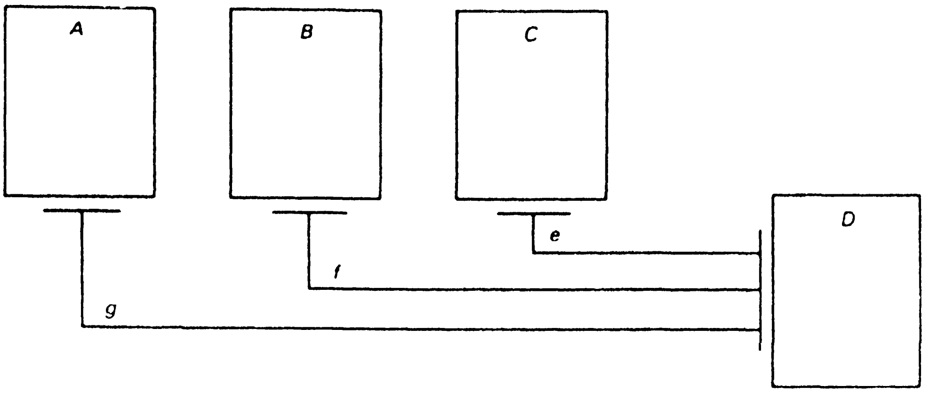
The test procedure corresponds to item a) of DD4.1.

b) *Closed pressure systems and sealed pressure systems*

The test procedure corresponds to item b) of DD4.1.

For closed pressure systems, the test may be performed at several stages of the manufacturing process or of assembling on site, on parts, components and sub-assemblies, according to the tightness coordination chart *TC*.

Gas-insulated metal-enclosed switchgear, single-phase encapsulated, circuit-breaker compartments of the three phases connected to the same gas system.



Leakage rate of the system

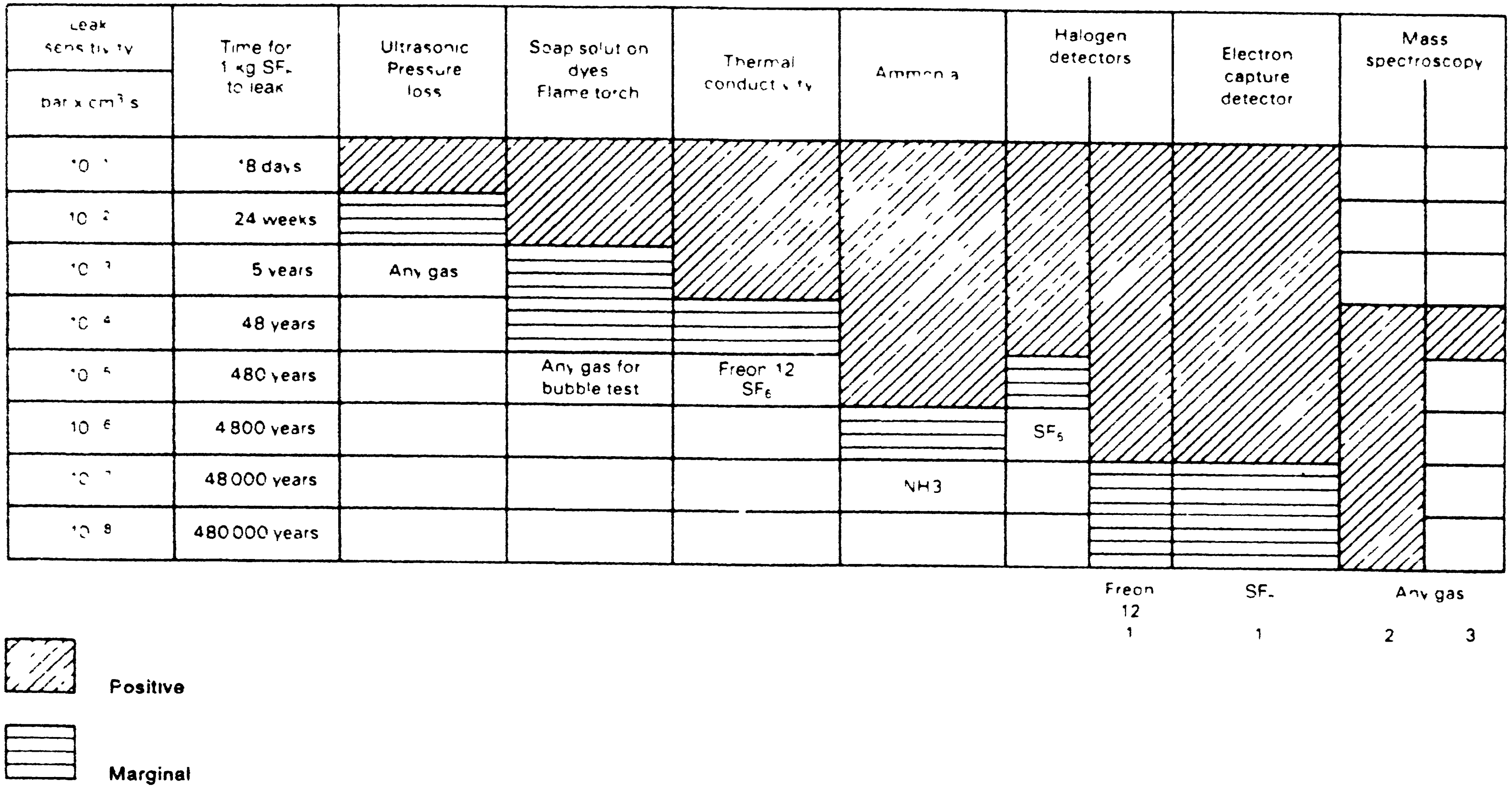
Compartment *A*	190×10^{-6} bar x cm³/s
Compartment *B*	190×10^{-6} bar x cm³/s
Compartment *C*	190×10^{-6} bar x cm³/s
Control box *D* (including valves, gauges, monitoring devices)	23×10^{-6} bar x cm³/s
Piping *e*	2×10^{-6} bar x cm³/s
Piping *f*	2×10^{-6} bar x cm³/s
Piping *g*	2×10^{-6} bar x cm³/s
Complete system	599×10^{-6} bar x cm³/s

Filling pressure	P_r: 6,0 bar (gauge)
Minimum functional pressure	P_m: 5,4 bar (gauge)
Total internal volume	270 dm³

$$F_{rel} = \frac{599 \times 10^{-6} \times 60 \times 60 \times 24 \times 365}{(6 + 1) \times 270 \times 10^3} \times 100 = 1{,}0\ \%\ \text{per year}$$

$$T = \frac{(6 - 5{,}4) \times 270 \times 10^3}{599 \times 10^{-6} \times 60 \times 60 \times 24 \times 365} = 8{,}5\ \text{years}$$

Figure DD1 – Example for a tightness coordination chart *TC*



NOTES

1 Sniffing in good conditions By integrated leakage measurement, better sensitivity can be achieved
2 In integrated leakage measurement
3 By sniffing

Figure DD2 - Comparison of leak detection methods

IEC
517

AMENDMENT 1

Page 14

Replace the title and the text of subclause 5 101 1 by the following

5 101 1 *Protection of persons against access to hazardous parts and protection of the equipment against solid foreign objects*

Refer to IEC 694

Page 15

Replace the title the text and table 1 of subclause 5 101 2 by the following

5 101 2 *Protection against ingress of water*

Refer to IEC 694

Page 18

5 103 3 *Gas tightness*

Add the following sentence

Refer to IEC 694

Replace the text of the first paragraph by the following

Because compressed gas is used for insulation, a high degree of tightness is required for the enclosure The permissible annual or daily escape of gas and the time between replenishments for each type of compartment and for the complete installation should be stated by the manufacturer

Add the following sentence to the second paragraph

In these conditions, the time between replenishments shall be not less than one month

Page 21

6 Type tests

Replace, on page 22, in the list of normal type tests, item f) by the following

	Subclause
f) Tests to verify the protection of persons against access to hazardous parts and the protection of the equipment against solid foreign objects	6 103

Page 31

Replace the title and the text of subclause 6 103 by the following

6 103 *Verification of the IP-coding*

Refer to IEC 694

Page 32

6 105 *Weatherproofing test*

Replace the text of this subclause by the following

When agreed between manufacturer and user, a weatherproofing test shall be made on gas-insulated metal-enclosed switchgear for outdoor use A recommended method is given in IEC 694

This test also takes into account the effects of wind-driven snow

If an examination of the design shows the test to be unnecessary, it may be omitted

Page 34

6 109 *Gas tightness tests*

Replace the text of the first paragraph by the following

Refer to IEC 694

Page 35

7 103 *Gas tightness tests*

Replace the text of the first paragraph by the following

Refer to IEC 694

Replace, on page 36, *the second sentence of the first paragraph by the following*

If requested, gas tightness tests may be made also on partitions if these are sealed off between both adjacent gas compartments by gaskets

Pages 54 to 60

Delete the text of Annex DD

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